European Journal of Geography Volume 7, Number 3:86 - 98, September 2016

THE FORMATION AND MORPHOLOGICAL CHARACTERISTICS OF ALLUVIAL FAN DEPOSITS IN THE RANGPO BASIN SIKKIM.

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Abstract

The present paper focuses on some observations and distinct findings about the formation and morphological characteristics of alluvial fans deposit in the Rangpo basin. Three alluvial fans have been taken under the study. It is an ample scope for studying the evolution and developmental strategies of alluvial fans being originated by both endogenetic and exogenetic forces. The geometry of fans are mainly controlled by the relating factors like relief, climate, lithology and the hydrographic characteristics of the streams. Fan development is a result of complex interaction of climate and tectonism being influenced by open hydrological system. It is observed from the study that the surface slope of the three coalesced fans being very steep has been carved out into agricultural terraces which are cultivated on a regular basis.

Keywords: *Exogenetic, Fan Head, Fan Boundary, Boulder, Terrace, Fan Surface.*

1. INTRODUCTION

A fan shaped mass of sediment especially silt, sand, gravel, and boulders, deposited by a river when its flow is suddenly slowed. It is a depositional landform of the lower course of the river. The present paper point out about 'The Formation and Morphological Characteristics of Fan Deposits in the Rangpo Basin'. The detail study about the nature and development of alluvial fans is concerned with the morphological arrangements and mode of occurrences both in a quantitative as well as qualitative. The mountain streams are debouching out on a flat plain, deposits its load, building up an alluvial fan. The geometry of fans is mainly controlled by the relating factors like relief, slope, climate, parent material, lithology and the hydrographic characteristics of the streams. It is an ample scope for studying the evolution and developmental strategies of alluvial fans being originated by both endogenetic and exogenetic forces.

There are several macro and micro fans have developed over the entire elongated Himalayan foothills of Sikkim with spectacular land use development being influenced by slope, water velocity, carried materials etc. The alluvial fan deposits are coarse grained poorly sorted and immature sediments. Usually boulders and gravels predominate with subordinate amounts of sand, silt and sometime clay. The size of materials is large and process of soil formation is hampered by regular flood deposits. The developments of fans are controlled by some integrated factors like: slope, climate, parent material, decrease of velocity etc. The piedmont zone of the foothills is well marked by the development of alluvial fans. This fan areas are also marked by variabilities of land use mainly agriculture is developed over the fertile alluvial deposits on which soil layers have prominently developed.

The main objectives of this study are to identification the morphological characteristics of the fans and to find out their spatiality variability. The study also analyzes the materials and sizes of the fans. The present researcher tries to understand the uses of alluvial fans of that region.

2. LOCATION

The Rangpo River is a right bank tributary to the Tista River at Rangpo town. It rises along the ridge on the international boundary between India and China at an elevation of 15509 ft of Nakchok Peak. Our area of field work is located somewhere in the immediate west of the confluence point at an around (27°12'18"N and 88°38'37"E). In the study area the Rangpo valley is wide open with a forest area along the left bank and a cultivated landscape around the right bank. However the cultivated area is not continuous and it mainly covers the area belonging to the alluvial fans and the river terraces.

3. METHODOLOGY

To fulfill the aforesaid objectives the present worker has adopted the modern methodology including the Remote Sensing and GIS. Most of the analysis of the study is based on intensive field work, data collection and empirical observations in terms of- (i) pre-field, (ii) field and (iii) post field methods with an application of advanced techniques of measurement and analysis. The first phase has been gone through an extensive literature survey to find out the trend and observation of previous work and the secondary data and maps have been collected from various sources. During the field survey different instrument like dumpy level, prismatic compass, G.P.S., accessories like tape, hammer, etc. have been used. A detailed G.P.S survey of alluvial fans was carried out during the field work. Such a survey determined the location of the fans, their traversing, measurement of elevation etc. In the post field session the data collected, is processed and fan profiles were constructed. Moreover, the co-relation between different bi-variate set of data is worked out and equations formulated graphical co-relation on the basis of such data has been done, through statistical method.

3.1. Literature Review

Denny (1965) showed normally the coarsest sediment will be found at the fanhead. When there fanhead trenching occurs, there is reworking and flushing of the sediment further downstream. Sometimes this results in a slight increase in the size of sediment along the fan radius. According to Bull (1977) fan materials are classified by Mud flow, braided stream flow and stream channel flow among which stream channel flow is responsible for the development of alluvial fans over this area. Bull has graphically summarized his observations on modern fans, and he has identified two situations. The first is when deposition is near the mountain front and the fan surface is undissected, and the second is when deposition is Hudson (1957) observed in Rhodesia that erosion increases exponentially with slope. Erosion is more active on a steep slope. As the slope increases the type of erosion and mass movement also change. For instance; vertical mass movement i.e. fall (rock fall, debris fall etc.) and landslide are active on steep slope while creeping (soil creep, rock creep, talus creep etc.) is dominated on moderate to gentle slope.at the toe of the fan and water and sediment move to this location through a trench. Strahler (1969), States that low rates of erosion allow the accumulation of thick weathering mantles which in progressively masking the underlying bedrock, gradually free river channels from structural controls.

Anstey (1965) has made a detailed comparison of fans in the great basin of the western United States, Baluchistan and Pakistan, and he demonstrates, from a sample of almost 2000 fans, that the greatest numbers of modern fans have radii between about 1 and 5 miles. Ryder (1971) showed the variability of sediment size on the fan surface is also encountered at depth; however, the overall vertical change in sediment size should be from finest at the base to progressively coarser at the fan grows up and out from the Canyon mouth.

4. FORMATION OF ALLUVIAL FAN

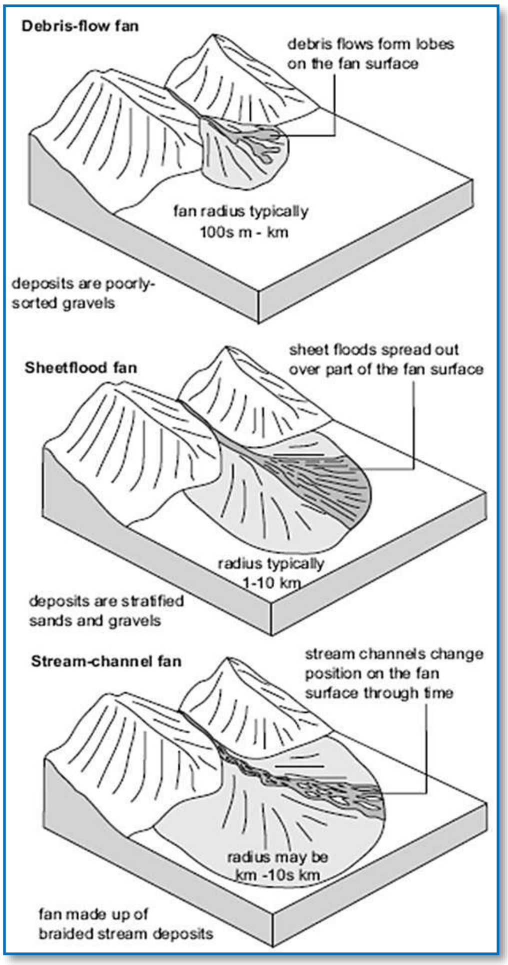
Rivers are an important feature of most landscapes, acting as the principal mechanism for the transport of weathered debris away from upland areas and carrying it to lakes and seas, where much of the clastic sediment is deposited.

River systems can also be depositional, accumulating sediment within channels and on floodplains.

The grain size and the sedimentary structures in the river channel deposits are determined by the supply of detritus, the gradient of the river, the total discharge and seasonal variations in flow. Water flows over the land surface also occur as unconfined sheet floods and debris flows that form alluvial fans at the edges of alluvial plains.

Three geomorphological zones can be recognized within fluvial and alluvial systems. In the erosional zone the streams are actively down cutting, removing bedrock from the valley floor and from the valley sides via downslope movement of material into the stream bed. In the transfer zone, the gradient is lower, streams and rivers are not actively eroding, but nor is this a site of deposition.

The lower part of the system is the depositional zone, where sediment is deposited in the river channels and on the floodplains of a fluvial system or on the surface of an alluvial fan.



Formation of alluvial fans. (Source: Mohamed)

As a stream gradient decreases, it drops coarse grained materials. This reduces the capacity of the channel and forces it to change direction and gradually built up a slightly mounted or pebbles shallow conical fan shape. The deposits are poorly shorted. This fan shaped can also be explained with a thermodynamic justification the system of sediment introduced at the apex of the fan will tend to a state which minimize the sum of the transport energy involved in moving the sediment and the gravitational potential of material in the fan. There will be iso-transport energy lines forming concentric arcs about the discharge point at the apex of the fan. Thus the material will end to be deposited equally about these lines, forming the characteristics fan shape.

5. LITHOLOGY OF THE STUDY AREA

The Rangpo basin crosses a number of lithological contacts. In the source area it is located well within the central crystalline Gneissic complex of the Kanchenjunga group. This formation is mainly confined to the north eastern corner and north western corner of the district. This Kanchenjunga formation extends mainly over an area delineated by the confluence of Rishi nala with Simana khola in the west, the lineament of Dhaula nala in the south and the confluence of Kiring Chu in the east. The north western exposure is found along the north western border of the district up to Rithu Khola region in the south.

The Daling group of rocks mainly consist of greenish Phyllites, Slates and Quartzitic mica Schist‟s. The Daling group of rocks mainly represents an argillaceous sequence ranging in age from Precambrian to Cambrian. Stratigraphically, the Daling groups of rocks are the oldest group of the meta-sedimentary rocks deposited over the basement complex. This group of rocks indicate very low grade of metamorphism. The basal part of the Daling group is represented by the Gorubathan formation, comprising mainly Phyllites of argillaceous composition and green Slates with Subordinate green Schist’s. The type area of this sub-group is Gorubathan. At the contact zone between the Darjeeling group and Daling group a mylonite Gneiss occurs. It covers for a length of about 1.5km. The Rongli Khola following the alignment of a fault drains into the Rangpo within this mylonite zone. A few hundred meters beyond the confluence towards west the Gorubathan formation. Here the river crosses number of lithological contact. In such sections various types of schist occur along with the phyllite. Our study concentrates on such a landscape where several litho contacts run across the river through the main country rock belongs to the Gorubathan formation. The rock beds in this area dip towards east at a range of 25° to 40°. However, a published map of G.S.I titled as District Resource Map records a maximum of 45°.

6. DRAINAGE PATTERN

Complex and diverse drainage characteristics in the Rangpo Basin offer a fascinating study for the evolution of landscape as well as land use pattern. Broadly, this river basin belongs to the Brahmaputra Drainage System. Regionally the entire area is drained by number of perennial rivers. The drainage system of the study area is controlled by the structure and neo-tectonic activity within the polygenetic activity. The drainage pattern includes mainly terraces, valleys, alluvial cones, truncated ridge-spurs, rectangular, braided, dendritic and radial drainage pattern being sculptured by both endogenetic and exogenetic forces. These are also supported by the peculiar modes of formation of the riverine topography primarily under fluvial environment. The fluvial landforms as well as drainage channel patterns have reflected several morphological characteristics being enabled with land use pattern.

7. CLIMATE AND NATURAL VEGETATION

Aritar (A town, located on the bank of Rangpo River and besides our study area) features a monsoon-influenced subtropical highland climate. Because of its elevation and sheltered environment, Aritar enjoys a mild, temperate climate all year round. Temperatures range from an average maximum of 25°C in summer to an average minimum of 4°C in winter. Summers (lasting from late April to June) are mild, with maximum temperatures rarely crossing 25°C. The monsoon season from June to September is characterized by intense torrential rains often causing landslides. Rainfall starts to rise from pre-monsoon in May, and peaks during the monsoon, with July recording the highest monthly average of 649.6 mm (25.6 inch).

The per-humid climate of the Rangpo basin in Sikkim is characterized with enormous water surpluses. The prevalent monsoon climates have supported evergreen (broad leaf) rainforests including grasses which become dense and luxuriant in some parts of the basin. It is important to note that depending upon the terrain properties e.g. structure, rocks in different geological formations, surface cover, and slope, the water surplus takes its course either through surface run off or deep percolation to underground regions. Practically, per humid climatic types are found in the whole mountainous terrain according to the moisture regime which plays a decisive role in the water potentialities of various sectors within the basin. Obviously, the southwest monsoon season which is the principle rainy period for almost the entire Rangpo basin is responsible for more than 80% of the total annual rainfall in these mountainous ecological sites, and significant in controlling the water balance.

8. ANALYSIS

Along the right bank slope of the Rangpo basin, a few alluvial fans have been formed. Among them 3 alluvial fans are coalesced. These three fans have been attached with each other through some overlapping section between 2 consecutive fans. In fact, these fans are little different from normal morphology of alluvial fans. They have sufficient difference of altitude between the fan head and fan rim or fan boundary. In that sense one may differ to call them alluvial fan. Two other fans are having discrete location, i.e. they located further west-ward. Interestingly the left bank of the river does not form any alluvial fan. The cause of formation is mainly related to the throwing of sediments by the minor rivulets subsequent to torrential rain. Sediment collected form upper ridges are thrown at the break of slope where they develop very steep fan like landforms, which may not be true fans in all cases.

8.1. Configuration of alluvial fan 1

This fan has a nearly flat fan head from where sediments spread downward forming a concave fan surface. The fan slope is 49^{o}. (Figure 1) This fan has been cut vertically by the Rangpo river and some fan terraces are formed. There are coarser particles at the upper part where as towards the lower reach particles are composed of finer sediments. The fan terrace is used for the purpose of agriculture as the fan debris are fertile and have a more or less stady flow of water inside. (Table 1)

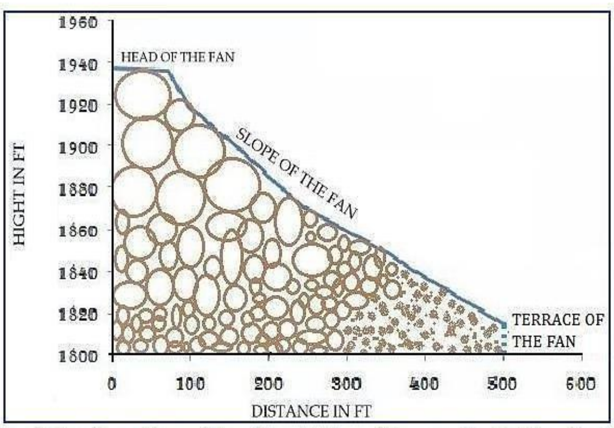


Figure 1. Configuration of the Alluvial Fan of Rangpo Basin [Fan No.1]

Table 1. Showing height according to distance data for fan 1.

Sl.no	Distance in ft	Diatance in height
1	0	1937
2	70.6	1936
3	97.4	1919
4	164	1898
5	218	1879
6	243	1871
7	290	1861
8	350	1849
9	390	1839
10	420	1833
11	500	1815

Source : Field Work,2013

8.2. Configuration of alluvial fan 2

This fan head is very steep from where sediments spread downward forming a concave fan surface. (Figure 2) This fan has been cut vertically by the Rangpo River and some fan terraces are formed. The fan slope is 69^{o} i.e. slope of the fan is very steep. At the lower part of the fan has a relatively gentle slope where some sort of agricultural work is done. (Table 2)

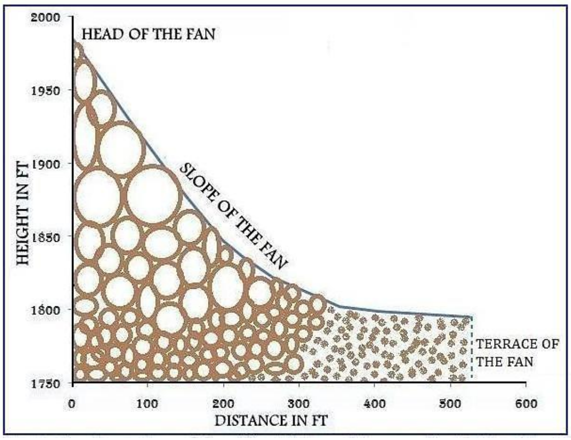


Figure 2. Configuration of the Alluvial Fan of Rangpo Basin [Fan No.2]

Table 2. Showing height according to distance data for fan 2.

Sl.no	Distance in ft	Diatance in height
1	0	1985
2	75	1930
3	150	1877
4	199	1847
5	225	1836
6	265	1822
7	300	1814
8	353	1802
9	404	1799
10	525	1795

Source : Field Work,2013

8.3. Configuration of alluvial fan 3

The fan surface of this is concave. (Figure 3) Fan head is very steep. The fan slope is 55^o. There are coarser particles at the upper part where as finer particles at the lower part. This fan has been cut vertically by the Rangpo river and some fan terraces are formed. (Table 3)

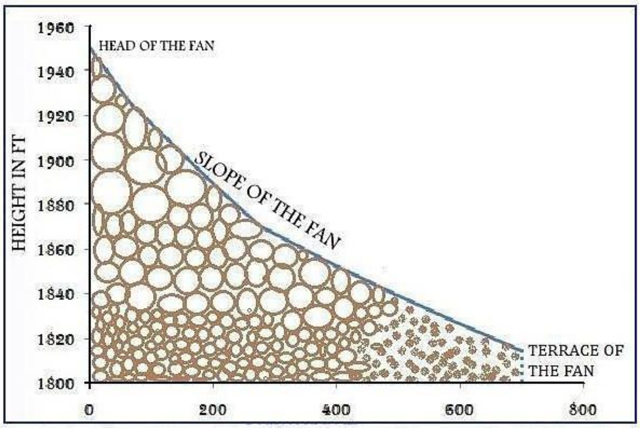


Figure 3. Configuration of the Alluvial Fan of Rangpo Basin [Fan No.3]

Table 3. Showing height according to distance data for fan 3.

Sl.no	Distance in ft	Diatance in height
1	0	1950
2	65	1925
3	100	1916
4	200	1889
5	274	1870
6	400	1852
7	500	1839
8	600	1826
9	700	1814

Source : Field Work,2013

8.4. Area of individual fan within coalesced fan deposits of Rangpo Basin

Three fans are coalesced with one another and a continuum of alluvial fans, alike a bajada in dry areas has been formed. (Figure 4) Of these three fans one is smaller in size (41.83m^2) when two others are, more or less, similar in size. The distribution of the fan sizes in a coalesced landform comprises 40% for fan-1, 15% for fan-2 and 45% for fan-3.
It may consider that the scope of deposition and availability of material is much higher in the case of fan-3.

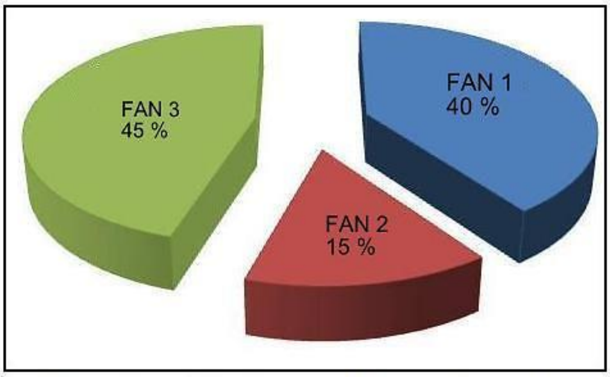


Figure 4. Area of Individual Fan within coalesced Fan deposits of Rangpo Basin.

8.5. The relation between fan size and slope and relief.

A related model was proposed by Echis, who suggested that trenching of fans will take place as sediment yields from the source area decreases through time during the normal progresses of the erosional cycle. Anstey (1965) made a detailed comparison of fans in the great Basin of the western United States, Baluchistan and Pakistan and he demonstrate, from a sample of 2000 fans, that the greatest numbers of modern fans have radii between about 1 and 5 miles (1.6-8km). Considerable scatter exits but considering the range of geologic and climatic conditions this is not surprising, and the fan without and understanding of the source area.

Fan size should be significantly related to size of the sediment source area. An example of this type of this relationship is provided Bull (1964) from the Fresno area, California. He shows that a good relationship exists between fan area and drainage basins area and that geology influences the relation, i.e. the intercept of the regression lines depending on lithology.

8.6. Relationship between Relief & Slope

Usually relief & slope are directly proportional to each other, as slope is practically an expression of relief. The same principal is observed in the alluvial fans of the Rangpo basin, higher the relief between the fan head and fan boundary, the steeper the slope. (Figure 5) When plotted on a graph with slope along the ordinate and relief along the abscissa a positive co-relation is obtained in the case study of all the three alluvial fans, of the Rangpo basin.

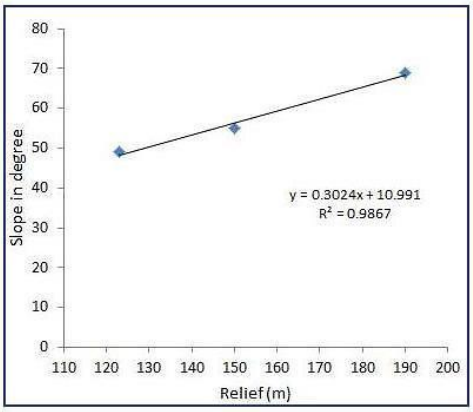


Figure 5. Relationship between Relief & Slope.

8.7. Relationship between radii and size

A radius is the main control of the circumference of a circle. (Figure 6) As an alluvial fan spreads from one center located at the fan head and the fan boundary forms an arc proportional to the radius, there is a direct relation between the radii of the alluvial fans and their sizes. (Table 4)

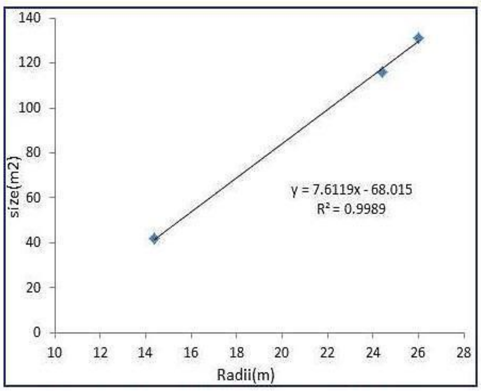


Figure 6. Relationship between Radii & Size.

Table 4. Showing data for relief, slope, radii and area of the fans.

Name of the Fan	Relief [m]	slope[degree]	Radii [m]	Size / Area[m2]
1	122	49	24.4	116.03
2	190	69	14.4	41.83
3	136	55	26	131.35

Source : Field Work,2013

The same principle is observed in the alluvial fans of the Rangpo basin. When plotted on a graph with Radii along the ordinate and Size along the abscissa a positive co-relation is obtained in the case study of all the three alluvial fans, of the Rangpo basin.

8.8. Fan structure.

Alluvial fan debris is poorly sorted due to the torrential deposition, especially near the fan head. The extent and pattern of the coarser forces is governed by a balance between basins size and relief, vegetation cover and hydrology and tectonic behavior of the mountain mass.

Normally the coarsest sediment will be found at the fan head. However, fan head trenching occurs, there is reworking and flushing of the sediment further to the downstream. Sometimes this result in the slight increased in the size of sediment along the fan radius (Denny 1965). Shifting pattern of deposition on an alluvial fan will result in considerable sediment variability. Lusting (1965) shows the distribution of reactive force on the antelope springs fan, and the figure permits an appreciation of how sediments are distributed over a fan surface at one stage in its growth. The variability of sediment size on the fan surface is also encountered at depth, however, the overall vertical change in sediment size should be from finest at the base to progressively coarser as the fan grows up but grain size should decrease as erosion reduces the source area. Fan size should be significantly related to size of the sediment source area.

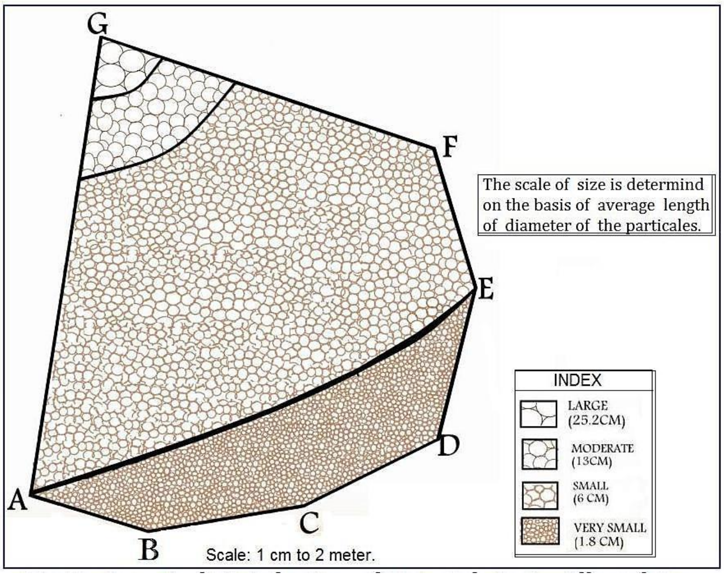


Figure 7. Area and Distribution of materials in an Alluvial Fan.

The alluvial fan which is totally exposed on the surface without any vegetation cover, one of the fans has been divided into four zones. (Figure 7) An average of 20 random samples of particles has been collected from each zone and average diameter has been determined. Thus we get four zones with four index diameters of the particles:

a) Large Boulder Zone: Diameter 25.5cm
b) Medium Boulder Zone: Diameter 13cm
c) Small Boulder Zone: Diameter 6cm
d) Gravel Zone: Diameter 1.8cm

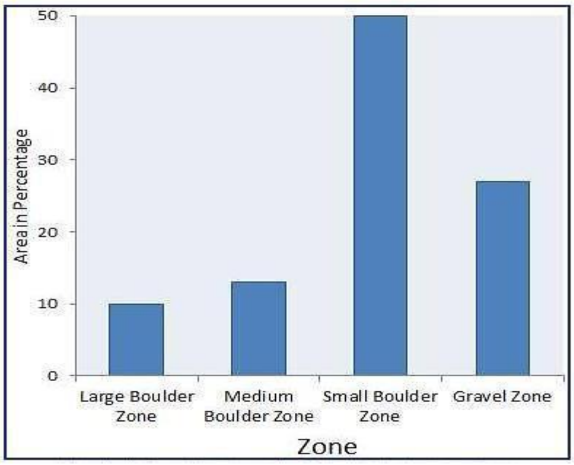


Figure 8. Distribution of materials according to area [%] in an Alluvial Fan.

Considering the specialty of this zone within the alluvial fan, it has been observed that the large boulder zone covers 10% of the area of the alluvial fan; medium boulder covers 13% of the area; small boulder zone covers 50% of the fan area and lastly the gravel zone covers 27% of the fan surface. (Figure 8) Thus it may be concluded that maximum materials belong to the small boulder zone. The large boulder being heavy are found only at the fan head, whereas the small gravels are thrown at the most distant places of the fan head.

8.9. Controls of Fan Development

The development of fans are controlled by some integrated factors like:

(i) Climate: The climate of the region is characterized by the per-humid type of climate with strong seasonal (June-October) distribution of rainfall. When precipitation is high the slopes of the alluvial fan remain gentle as the flow of water shifts the sediments and decreases the gradient. Actually, heavy rainfall increases the flow of water with huge amount of sediments.

(ii) Lithology: The lithology of the rock character is another controlling factor for the deposition of fans. The entire study area contained comparatively less coarse materials are not so large, steep.

(iii) Hydrological Characteristics: large amounts of debris deposited on the alluvial fans which are widely expand over the Himalayan foothills. On the fan surface the trunk streams feds the distributary channels and water discharge diminishes along its course. Moreover, as the fans consist of more permeable sediments, additional discharge is lost because of downward water percolation (Mukhopadhyay, 1982). This discharge promotes the rate of deposition.

(iv) Slope: Slope is another influencing factor for deposition of fans. The sudden break of slope in the southern part helps to deposit the carried materials. But range of slope decreases.

8.10. Use of alluvial fan

The alluvial fans which are old enough to develop soils on them and such materials have been of great use for the local inhabitants. The surface slope of the three coalesced fans being very steep has been carved out into agricultural terraces which are cultivated on a regular basis. The alluvial fans having a good hydrological condition supply the required amount of water which keeps the fan surfaces reasonably moist. Moreover the fan materials are lose and fine because of a long period of weathering and associated soil forming process. Hence the local inhabitants use the fans surfaces as readily usable cultivated fields. Thus the alluvial fans have been a resource of high potentiality for the area.

9. CONCLUSION

The Rangpo basin having a great number of litho-units with variable resistance and high relative relief has developed complex hydraulic characteristics where hydraulic drops and hydraulic jumps are regular features. The large scale piedmont terraces with extensive flat alluvial fan deposits are formed by the result of progressive flattening of the gradient of the major tributaries of Rangpo River. From the study it is concluded that the developmental strategies of alluvial fans being originated by both endogenetic and exogenetic forces. There are several macro and micro fans have developed over the area with spectacular land use development being influenced by slope, water velocity, carried materials etc. So far the proper management of agriculture production needs sufficient irrigation system improving the methods.

ACKNOWLEDGEMENTS

The researcher wishes to offer his indebtedness and gratefulness to his teacher and guide Dr. Partha Basu, M.A, Ph.D., and Formerly Associated Professor, Department of Geography, Bhairab Ganguly College who has supervised this work and provided his valuable suggestions and continuous encouragement in this undertaking. I would also like to thank my fellow friend Aditi Sharma who helped me at every stage of this paper.

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